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THE SIMULATION OF TACTICAL DECISION PROCESSES

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INTRODUCTION

- APPLICATIONS OF SIMULATION TO C^3I RESEARCH AND DEVELOPMENT

  - DEVELOPMENT

    - HARDWARE SIMULATION
    - TESTBED ENVIRONMENTS
    - DECISION AID RESEARCH

  - OPERATIONS/TRAINING

    - TRAINING EXERCISES
    - OPERATIONAL/DEVELOPMENTAL TESTS

  - ANALYSIS

    - INFORMATION FLOW
    - COMBAT OPERATIONS
    - TOTAL SYSTEM PERFORMANCE

- THIS BRIEFING FOCUSES ON ONE CRITICAL ASPECT:

  - THE SIMULATION OF TACTICAL DECISION PROCESSES

SLIDE 1

Any examination of information processing and decisionmaking in tactical command and control would not be complete without addressing the role of simulation. As shown here, examples of simulation can be found throughout various communities involved with C3I.

Within the development community, simulation models are used to analyze advanced hardware performance, to provide simulated combat environments for hardware testbeds, and to conduct decision aid research. Current applications include such efforts as the Advanced Sensor Exploitation program, the Battlefield Exploitation and Target Acquisition (BETA) project, and the Distributed Data Processing System Topology Evaluation capability.

Similar efforts by the operations and training communities have also exploited the advantages of simulation. The Air Force's BLUE FLAG program, for example, uses simulation to provide much of the combat environment for its battlestaff training.

Within the analytical community, simulation modeling has become a prime tool for investigating information flow and the contribution of C3I systems to overall force effectiveness.

The wide application of simulation to C3I research and training makes it rather impractical to attempt a total discussion of the subject within a single briefing. Rather, I would like to focus on what we have come to believe is a critical aspect of C3I simulation. Specifically, I would like to discuss the progress we have made in simulating tactical decision processes.

I have chosen this topic because of its central importance in most C3I issues and because of its inherent difficulties. The difficulties of simulating real-world decision processes reminds me of a proposition from John Gall's book, Systemantics:

> "All systems are infinitely complex...The illusion of simplicity comes from focusing attention on one or a few variables."
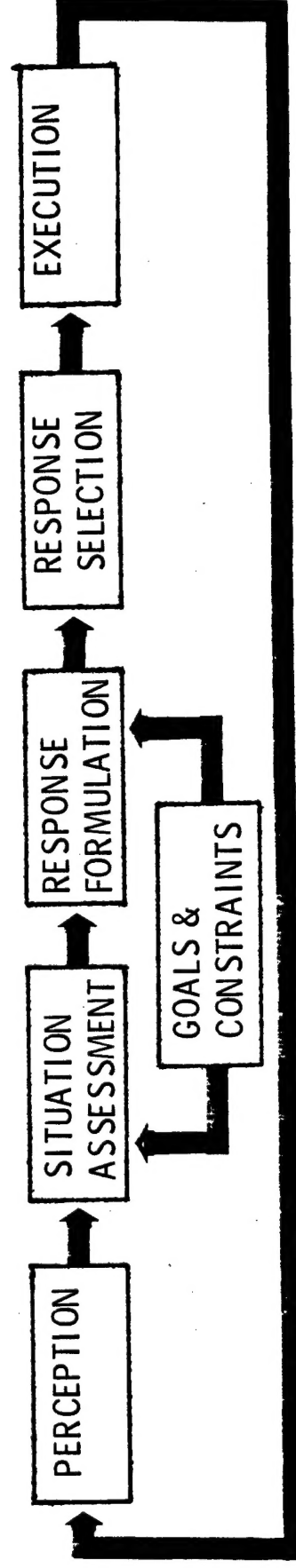
WHAT IS MEANT BY THE SIMULATION OF TACTICAL DECISION PROCESSES?

SIMULATION DEFINED:

A MODEL WHICH EMULATES THE ESSENTIAL FEATURES OF A REAL SYSTEM

- UNDERSTANDING SYSTEM BEHAVIOR
- EVALUATING ALTERNATIVE STRATEGIES AND SYSTEM COMPONENTS
- ASSESSING SYSTEM PERFORMANCE AND UTILITY

A SIMPLE MODEL OF DECISION PROCESSES:

PERCEPTION → SITUATION ASSESSMENT → RESPONSE FORMULATION → RESPONSE SELECTION → EXECUTION

GOALS & CONSTRAINTS

SLIDE 2

Before jumping into a discussion of our progress in this area,
I would like to take a few moments and explain precisely what I
mean by the "simulation of tactical decision processes."

As most of us recall, simulation can be defined as building a
model which emulates (or reproduces) the essential features of a
real world system. we build such models for several reasons: to
understand system behavior, to stress and evaluate components, and
to assess system performance and utility.

Systems can be defined at several levels. We can consider the
entire tactical force to be a system made up up of weapons,
support equipment, people, procedures, and so on. Within that
overall system, we can move down to those hardware elements,
people, and procedures which make up a C3I system. Within the C3I
system we can also choose to define the human decisionmakers as a
system, albeit a very distributed one in most cases. For this
briefing, I would like to focus on a single decisionmaker and
discuss our present ability to address that decisionmaker as a
system within our simulation models.

A very simple view of our decisionmaker is shown at the bottom
of this chart. Here I have outlined the general tasks our
decisionmaker performs within the C3I system. These tasks are
generic in the sense that they can be applied to a wide variety of
force management decisions faced by a commander, a member of his
battle staff, a pilot, or so on.

I don't claim that this model is unique or even the best one
we could imagine. Rather, I show it to you to give a general
feeling for what I'm going to talk about in a moment.

EXAMPLES OF TACTICAL DECISION PROCESSES
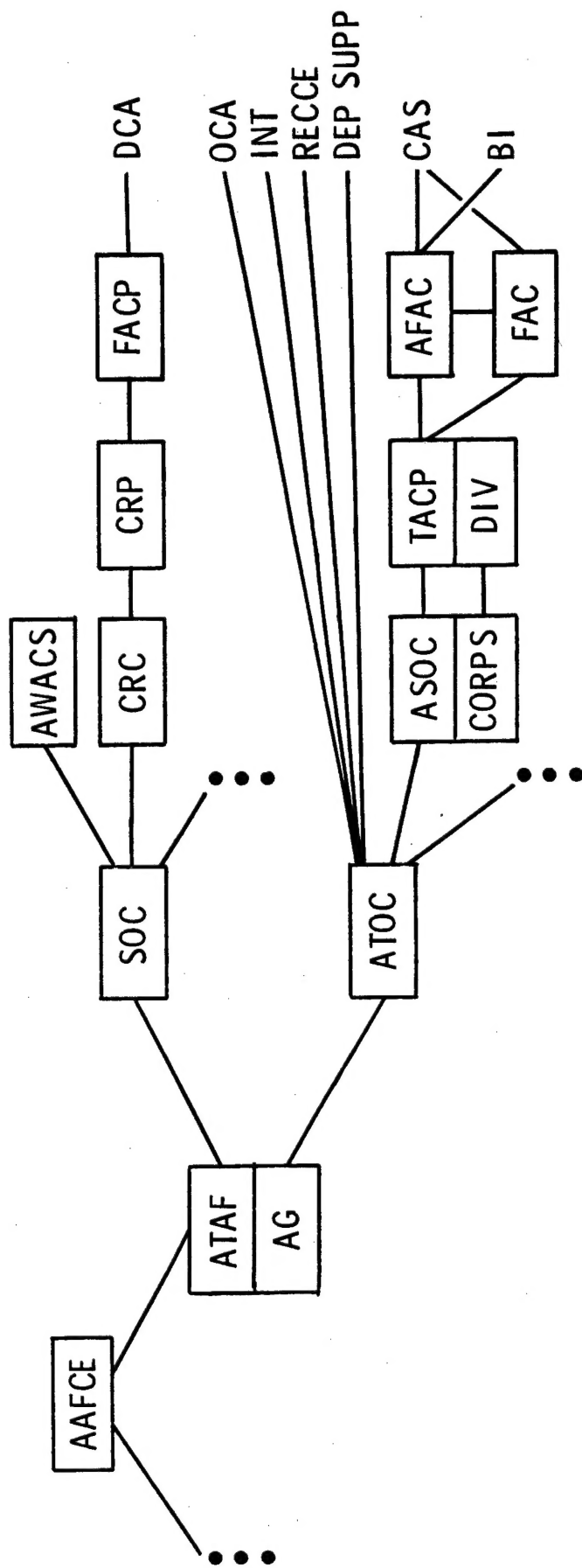
PLANNING & COMMITMENT

- APPORTIONMENT
- ALLOCATION
- TASKING/COORDINATION
- DETAILED UNIT PLANNING

CONTROL & COORDINATION

- REALLOCATION
- TARGET REASSIGNMENT
- TARGET UPDATE
- THREAT WARNING

SLIDE 3

To further illustrate where our interest lies, I show a typical C3I system. In this example, it is the Tactical Air Control System found in the Central European Region of NATO.

Now what I have shown at the top of the chart are the C3I elements which control the various air mission listed to the right of the chart. Below are the general types of functions performed by this distributed system.
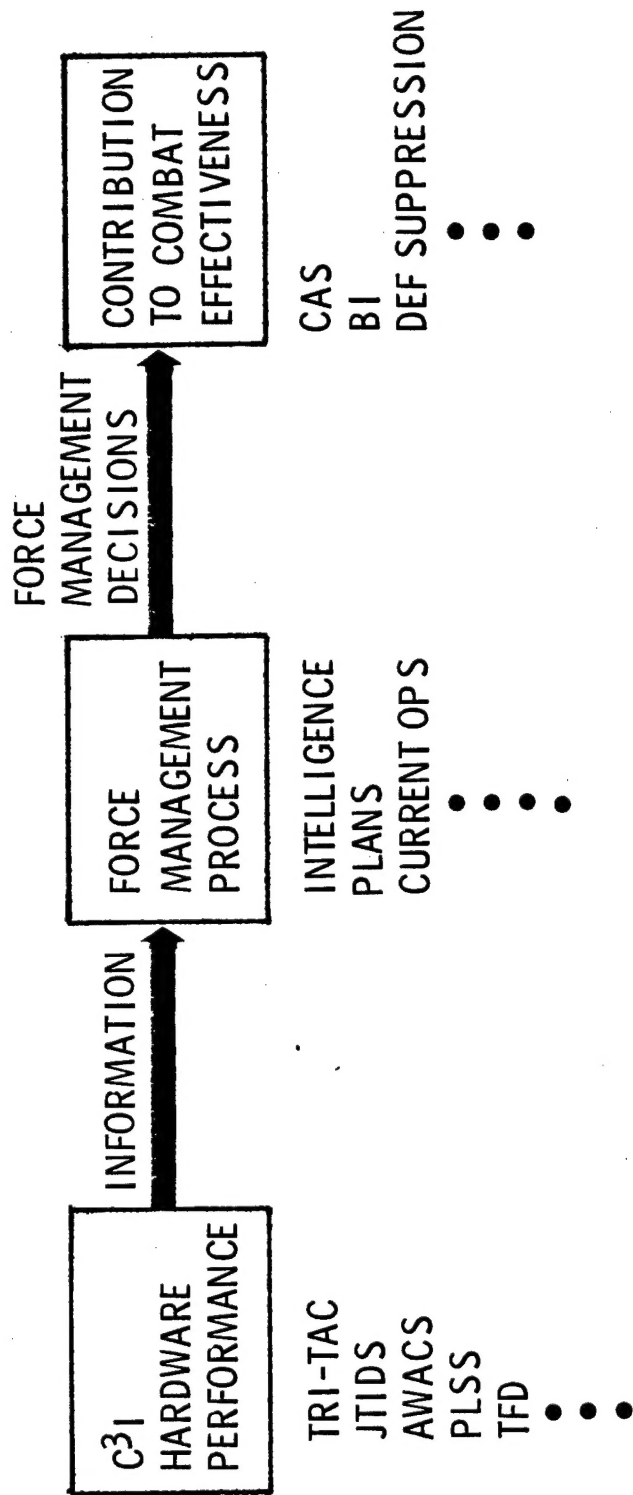
In examining this C3I system, I would like to make several points. First, we could take our general model of a decision process and apply it to each of the functions listed. That is to say, decisions are not made by automated data processing systems or other machines. Rather, they are made by human beings who apply subjective reasoning in developing plans, tasking, control directives, and so on.

The second point I make is the fact that numerous individual decision processes are occurring simultaneously within different parts of this system. What we can generally observe from watching the operation of this system is the collective product of all of these decision processes. An (perhaps, oversimplified) analogy from engineering might state that we have a system governed by a lot of simultaneous differential equations.

Now, instead of carrying that analogy any further, I would like to move on to discuss why we are interested in better understanding this type of distributed decision process. {Believe me, we don't get paid to study this problem for the sheer fun of it!}

SYSTEM PERSPECTIVES

C³I
HARDWARE
PERFORMANCE

TRI-TAC
JTIDS
AWACS
PLSS
TFD
• • •

INFORMATION →

FORCE
MANAGEMENT
PROCESS

INTELLIGENCE
PLANS
CURRENT OPS
• • • •

FORCE
MANAGEMENT
DECISIONS →

CONTRIBUTION
TO COMBAT
EFFECTIVENESS

CAS
BI
DEF SUPPRESSION
• • •

SLIDE 4

To begin a discussion of why we are interested in tactical decision processes, I would like to first discuss C3I from various system perspectives. As I suggested earlier, we are dealing with several systems, each imbedded within another.

At one system level we focus on the hardware and software components which support the tactical desicionmakers. Typical components might include communications systems such as TRI-TAC or JTIDS; sensor systems such as Fusion Division equipment (a follow-on to BETA).

It is important to note what these hardware and software systems generally do and don't do. What they do is provide information to the human decisionmakers who make the force management decisions. What they don't do is make those force management decisions, themselves.

At the second level, we find the human decisionmakers operating with the hardware/software systems of the first level, and with the procudures, experiences, and doctrine associated with specific functions. This second level provides the force management decisions which guide the deployment and employment of combat forces.

At the third system level, we find the force management process combined with weapon systems to produce some measure of effectiveness. The measure of combat effectiveness achieved is thus seen to be influenced by the force managmenet process, but not totally determined by it. Recalling in earlier phrase applied to C3I systems, we see that "force multiplier" is not a constant value. Rather, the "force multiplier" contribution of C3I can, itself, be influenced by weapons effectiveness, force structure, scenario, enemy objectives, and so on.

THE IMPORTANCE OF
INCLUDING DECISION PROCESSES IN C³I ANALYSIS

- C³I HARDWARE/SOFTWARE REQUIREMENTS DEFINITION

  - INFORMATION FUSION
  - DISPLAY OPTIONS/FORMAT
  - DECISION AIDS
  - COMMUNICATIONS LOAD
  - SENSOR CHARACTERISTICS

- C³I SYSTEM ARCHITECTURE DEFINITION

  - INFORMATION EXCHANGE
  - CENTRALIZED/DECENTRALIZED DECISIONS
  - PROCEDURAL/POSITIVE CONTROL
  - MISSION COORDINATION

- C³I SYSTEM UTILITY ASSESSMENT

  - THE LINK BETWEEN C³I HARDWARE PERFORMANCE AND COMBAT EFFECTIVENESS

SLIDE 5

So why the fuss over tactical decision processes? As shown in this chart, I list several reasons for our interest in better understanding tactical decision processes.

First, our understanding of decision processes is a key ingredient to defining C3I hardware and software requirements. Since these systems are supposed to supply information to the force manager, we had better make sure they are supplying the right information. What information is "right" depends upon the nature of the decision process using it. And I might add that our general notion of "the right information" precludes information which is superfluous to the decision processes. This concern over superfluous information is heightened by the prospect that future ADP and communications systems may be easily capable of flooding the commander with tons of irrelevant data.

Second, I recall the distributed nature of tactical decision processes and note the importance of properly defining C3I system architecture. A key issue here is in understanding the type of decisions made at each point in the C3I system, the nature of those corresponding decision processes, and the availability of "the right information" at each point.

Finally, the three system perspectives shown earlier suggest that tactical decision processes are the link between C3I hardware performance and combat effectiveness. Thus, if we are to understand something about the marginal utility associated with different ADP or communication systems, we had better address the decision processes which utilize those systems.

Now key to the role of simulation in this matter is our general desire to provide quantitative insight into each of these three areas. We could rely (and often have) on the subjective judgment of experienced operators to define hardware requirements, system architecture, and system utility. To suggest that we are attempting to completely replace this judgment with quantitative analysis is incorrect. Rather, as in many other areas of systems analysis, we are attempting to extend our quantitative knowledge about C3I as an assistance to such judgment.

AN EXAMPLE OF AN EARLIER ANALYSIS

OBJECTIVE: QUANTIFY THE MARGINAL UTILITY OF AN IMPROVED TACTICAL DATA DISTRIBUTION SYSTEM TO CLOSE AIR SUPPORT OPERATIONS

POSTULATED BENEFITS:

- REAL-TIME BATTLEFIELD PICTURE FOR FAC
- IMPROVED AIRCRAFT NAVIGATION
- IMPROVED AIRCRAFT IDENTIFICATION
- MORE TIMELY DIVERT NOTIFICATION
- REDUCTION OF MESSAGE ERRORS
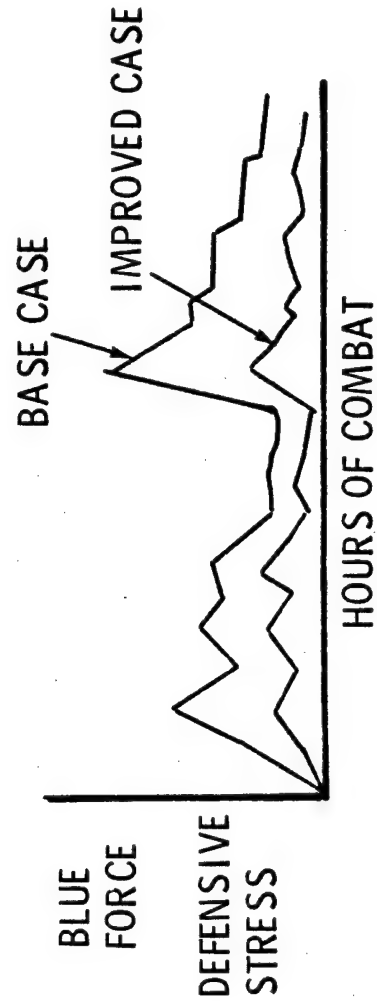- BACK-UP CAPABILITY FOR FAC

ASSUMED RESULT OF BENEFITS:

POTENTIAL INCREASE OF X % IN EFFECTIVE CAS SORTIES FOR A GIVEN FIGHTER FORCE STRUCTURE

CORPS-LEVEL AIR/LAND COMBAT MODEL

BLUE FORCE DEFENSIVE STRESS

BASE CASE

IMPROVED CASE

HOURS OF COMBAT

SLIDE 6

   I show a brief example to illustrate our concern. This
example is taken from the briefing Major General Welch gave during
the preceding symposium we jointly hosted with ESD in 1978.

   During that briefing, General Welch illustrated an attempt to
quantify the marginal utility of procuring JTIDS for the tactical
air forces. One mission area analyzed in that effort was close air
support operations.

   A slide was presented showing the postulated benefits of JTIDS
to CAS operations. These benefits were postulated by experienced
operators familiar with CAS operations. Unfortunately, we had no
means at the time of explicitly verifying either the validity of
these postulations, or the resultant impact on CAS operations. In
the end, we were reduced to assuming that these benefits would
somehow translate into a percentage increase in effective CAS
sorties.

   Of course, once this assumption was made, it became a
straightforward process to use an existing combat simulation model
and quantify an appropriate measure of combat effectiveness. In
this case, the "benefit" of JTIDS was reflected as a decrease in
defensive stress along the forward edge of the battle.

   The point of this example is to illustrate a critical "missing
link" to our analysis. The missing link was our understanding of
how an improved communications system might result in an increase
in effective CAS sorties. Hence, out of many such frustrations
grew our desire to better understand the critical role of tactical
decision processes.

APPROACHES TO SIMULATING TACTICAL DECISION PROCESSES

● MAN-IN-THE-LOOP DECISION MAKERS

    ADVANTAGES:
- INHERENT FIDELITY (LIMITED)
- STRAIGHT FORWARD IMPLEMENTATION

    DISADVANTAGES:
- EXPENSIVE
- INCONSISTENT BEHAVIOR
- LACK OF INSIGHT INTO DECISION PROCESSES

● CYBERNETIC MODELS OF DECISION PROCESSES

    ADVANTAGES:
- DECISION PROCESSES ARE EXPLICIT
- REPEATABLE, CONGRUOUS BEHAVIOR
- INEXPENSIVE

    DISADVANTAGES:
- LIMITED FIDELITY AND ROBUSTNESS

Now, in general, there are two basic approaches to simulating tactical decision processes. You can employ real people to assume the role of specific decisionmakers in the simulation exercise. Examples are the TALON model at TFWC Studies and Analysis and the BLUE FLAG exercise at TAWC. Or you can attempt to build quantitative models (or cybernetic models as I shall call them) which emulate the behavior of specific decisionmakers.

I have listed here the general advantages and drawbacks of each approach. The advantages of man-in-the-loop decisionmakers are their inherent fidelity and ease of implementation. I say "inherent fidelity" because nothing simulates a real person like a real person. Yet, fidelity can still be a problem if proper attention is not given to selecting test subjects with appropriate knowledge and experience. In addition, realistic conditions of stress may also be difficult to reproduce in the simulated C3I environment.

The disadvantages of man-in-the-loop decisionmakers include their expense and the potential for inconsistent behavior. Additionally, the analyst is afforded little insight into the decision process. We may observe the decisions made, but not the process of how they were arrived at (what information was critical, what patterns were perceived and found significant, how was the problem viewed, and so forth).

Cybernetic models of decision processes are, by their nature, explicit, repeatable, and congruous. They are, after all, mathematical models which we have created ourselves. But, because they are mathematical models of our own making, they tend to have limited fidelity and robustness. That is, we are reducing complex thought processes down to a set of mathematical computations.

From an analytical point of view, the idea of a cybernetic model is most appealing. If we could somehow make that model more realistic, it would represent the ideal tool for studying the role of tactical decision processes in C3I systems. In fact, some of our current models may already be quite adequate for certain types of simulation efforts. Hence, I would like to focus on cybernetic models for the remainder of this briefing and give you some idea of our progress in this area.

CYBERNETIC MODELS - EXAMPLE 1

IMMEDIATE AIR REQUEST PROCESSING
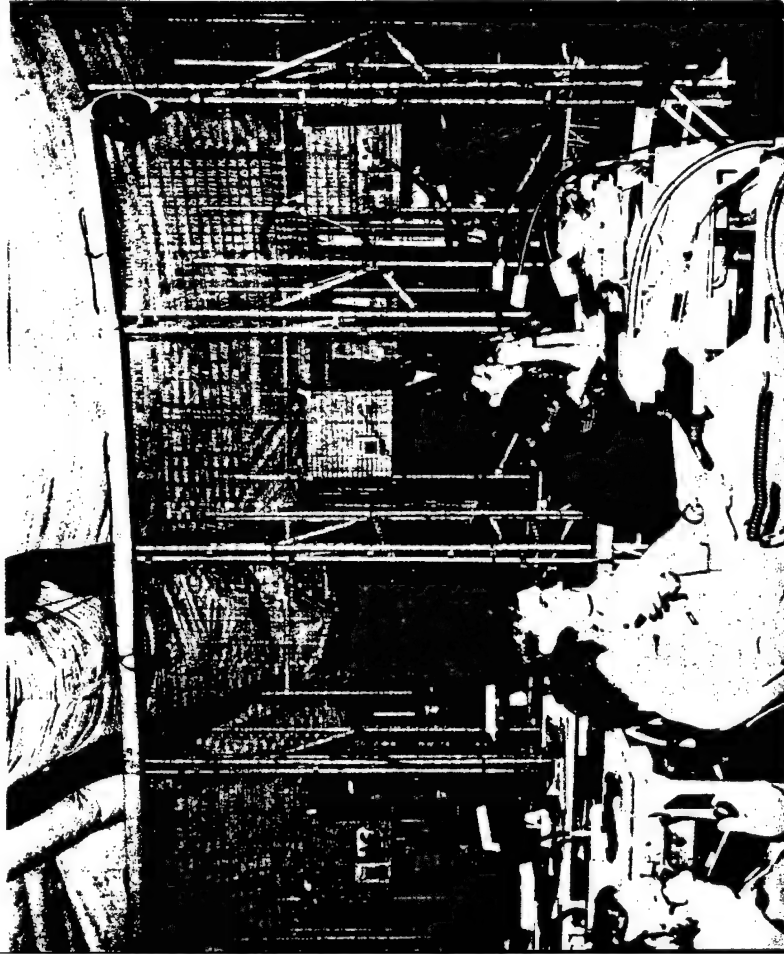
DECISION PROCESS:

ALLOCATION OF APPROPRIATE CAS
SORTIES IN RESPONSE TO IMMEDIATE
AIR SUPPORT REQUESTS

FACTORS TO CONSIDER:

- HAS HIGHER HEADQUARTERS DENIED REQUEST?

- WHAT AIRCRAFT ARE AVAILABLE DURING THIS TIME BLOCK?

- WHAT IS THE MOST APPROPRIATE MATCHUP OF AIRCRAFT/ORDNANCE TO THE TARGET?

- CAN AIRBORNE ALERTS OR LOWER PRIORITY MISSIONS BE DIVERTED TO SATISFY THE REQUEST?

- WHAT INFORMATION IS REQUIRED TO COMPLETE THE TACTICAL AIR PLAN AND CREATE A FRAG ORDER?
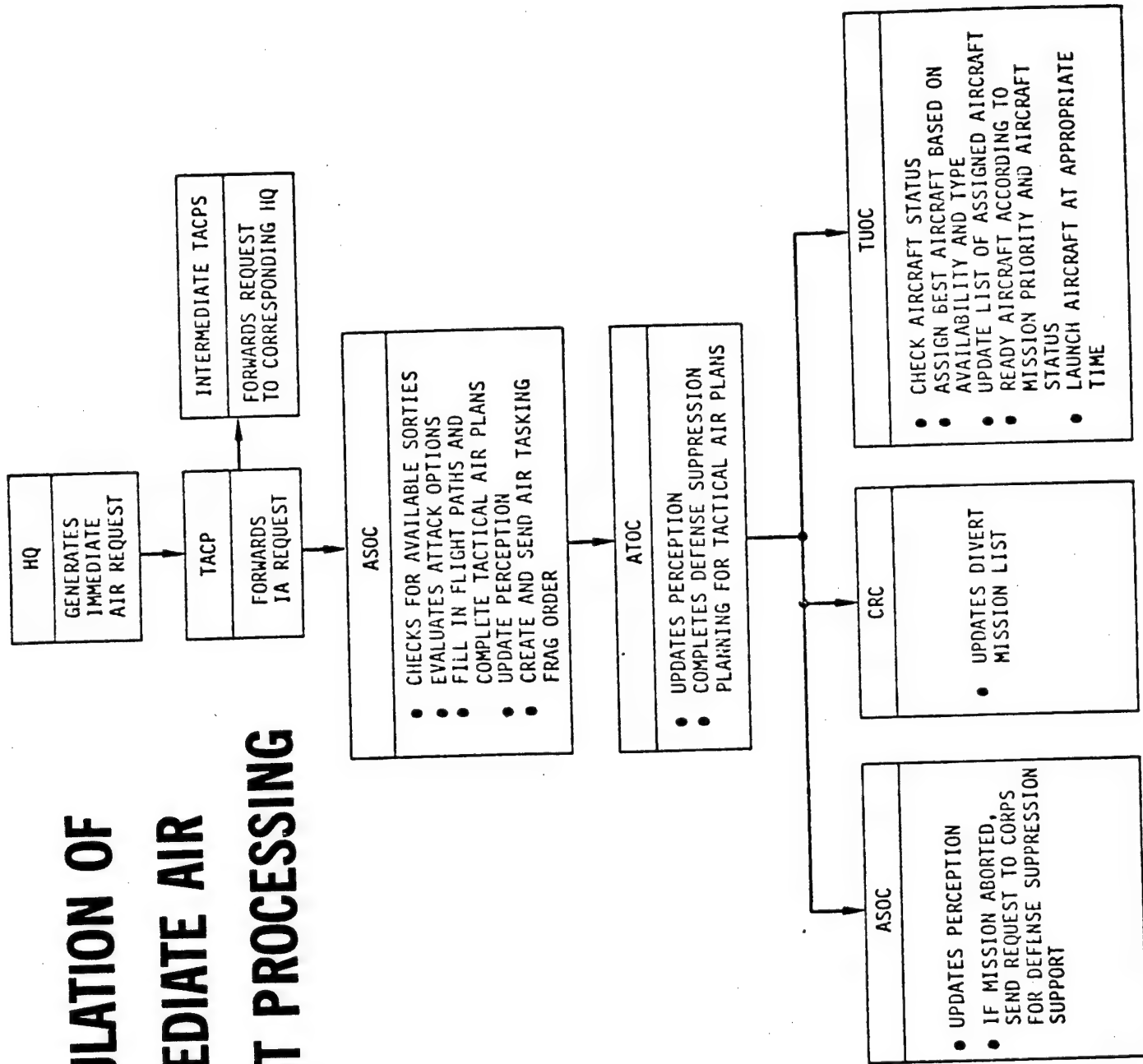
SLIDE 8

In discussing our progress with cybernetic models, I would like to briefly present examples of two such models. Both of these examples are taken from our TAC ASSESSOR model in Air Force Studies and Analyses. The TAC ASSESSOR Model simulates a combined air/land battle along with the explicit C3I structures which govern both the air and land forces for each side. Extensive use is made of artificial intelligence techniques to simulate the appropriate planning, commitment, controlling, and coordination decisions associated with a Tactical Air Control System and a Corps-level ground force.

The first example is taken from our model of the ASOC's decision processes concerning immediate air requests. The task to perform here is the dynamic allocation of appropriate CAS sorties in response to the Corps's immediate air requests.

Shown below are the factors the ASOC personnel might consider as part of their sortie allocation process.

Before turning to the simulation model of this process, I would like to stress that our goal in TAC ASSESOR is not to simulate optimum rationale decision behavior. Rather, we are attempting to simulate real world behavior. In TAC ASSESSOR we have avoided the use of sophisticated optimization techniques for producing decisions unrepresentative of those in a real ASOC. In the words of the author Charles Lindblom, we are attempting to simulate the "science of muddling through decisions."

SIMULATION OF IMMEDIATE AIR REQUEST PROCESSING

HQ
GENERATES IMMEDIATE AIR REQUEST

TACP
FORWARDS IA REQUEST

INTERMEDIATE TACPS
FORWARDS REQUEST TO CORRESPONDING HQ

ASOC
• CHECKS FOR AVAILABLE SORTIES • EVALUATES ATTACK OPTIONS • FILL IN FLIGHT PATHS AND COMPLETE TACTICAL AIR PLANS • UPDATE PERCEPTION • CREATE AND SEND AIR TASKING FRAG ORDER

ATOC
• UPDATES PERCEPTION • COMPLETES DEFENSE SUPPRESSION PLANNING FOR TACTICAL AIR PLANS

TUOC
• CHECK AIRCRAFT STATUS • ASSIGN BEST AIRCRAFT BASED ON AVAILABILITY AND TYPE • UPDATE LIST OF ASSIGNED AIRCRAFT • READY AIRCRAFT ACCORDING TO MISSION PRIORITY AND AIRCRAFT STATUS • LAUNCH AIRCRAFT AT APPROPRIATE TIME

CRC
• UPDATES DIVERT MISSION LIST

ASOC
• UPDATES PERCEPTION • IF MISSION ABORTED, SEND REQUEST TO CORPS FOR DEFENSE SUPPRESSION SUPPORT

SLIDE 9

Shown in this chart is an overview of how immediate air requests are simulated in the TAC ASSESSOR model. The appropriate ground headquarters model generates the request in response to an engagement with an enemy unit. I might mention that another, entirely independent decision model is operating for the ground headquarters. This separate model might be requesting artillery support, reinforcements, or a change of mission assignment, in addition to requesting air support.

The TACP model passes the request message both to the ASOC model and to the intermediate TACPs associated with higher ground headquarters. Within a preset time, one of these intermediate headquarters may decide to cancel the request. If the preset time elapses without the ASOC receiving a cancellation message, the ASOC proceeds to complete its planning process as shown. Within the model, techniques such as production rule systems and signature tables are employed to reflect the decision rules used in this planning.

Assuming an appropriate match-up has been found, the ASOC model creates and passes an air tasking message up to the ATOC model. At the ATOC, separate decision models determine the necessity for additional defense suppression sorties. Following this, the completed air tasking message is forwarded to other elements in the system and additional decision models are invoked.

The point of this example is to illustrate that a number of related, but independent decision processes are associated with the planning and execution of this type of air mission. A number of these decision processes are occurring simultaneously. Each decison process acts on the basis of only that information provided to it via communication links. Information may be late, erroneous, completely missing, and the TAC ASSESSOR model is used to examine the impact of this on tactical decisions. Hence, the analytic capabilities of this type of model begin to be appreciated.

CYBERNETIC MODELS - EXAMPLE 2

AIR MISSION EXECUTION

DECISION PROCESS:

EXECUTION OF APPROPRIATE ACTIONS
AND REPORTING DURING AN AIR MISSION

FACTORS TO CONSIDER:

- HOW DOES THE AIRCRAFT RESPOND TO
  MESSAGES RECEIVED FROM A CRC, CRP,
  FACP OR FAC?

- IS THERE ENOUGH FUEL TO COMPLETE THE
  REMAINDER OF THE MISSION?

- WHAT ARE APPROPRIATE ACTIONS TO TAKE
  AT VARIOUS POINTS IN THE AIR MISSION?

While the ASOC example illustrates the modeling of a specific air planning process, this next example relates to the execution of certain air missions.

Again, we see the corresponding real-world decision process outlined in this chart. Here, we are concerned with the moment-to-moment decisions made by a pilot as he executes a scheduled air mission.

The general factors considered relevant to this decision process are listed below. The decision process shown here varies from the previous example in several ways. First, the time scale for reaction is much shorter than that for the ASOC. Secondly, the pilot has direct control over a specific weapon system. And, third, the pilot is directly interacting with the combat environment.

On the other hand, the decision process shown here has some commonality with the previous example. The pilot still receives general instructions and certain types of information via communication links. And, while the pilot may have the benefit of certain direct observations of the combat area, he must still form a portion of his total perception on the basis of information received from others. In addition, his decision process is also guided by prescribed rules and procedures.

SIMULATED AIR EXECUTION DECISIONS

TUOC

(1) BRING ALL A/C ON TACTICAL AIR PLAN TO LAUNCH STATUS

(2) CREATE PILOT DATA SET

(3) INITIATE PILOT ACTION

CC MSG →

PILOT

CC MSG	CONTINUE FLIGHT	ARRIVED AT A PATH POINT	EVENT HAS OCCURRED	

CC MSG

(1) UPDATE POSITION & FUEL

(2) ACCEPT NEW FLIGHT PATH

(3) CONTINUE FLIGHT

CONTINUE FLIGHT

(1) CHECK FUEL IF ENOUGH, PROCEED TO NEXT PATH POINT

ELSE, RETURN TO BASE

ARRIVED AT A PATH POINT

UPDATE POSITION AND FUEL
CHECK FOR ATTRITION
IF EXCESSIVE, RETURN TO BASE

POINT TYPE	ACTION
CCTR	SEND CC MSG, WAIT PRESCRIBED TIME, PROCEED
FAC	SEND CC MSG, PLACE SELF ON LOITER
AALT	SEND CC MSG, WAIT PRESCRIBED TIME, SEND ANOTHER MSG
BASE	TURN IN A/C, MAKE FINAL REPORT
TGT	MAKE DAMAGE REPORT
RCNS	MAKE RECON PASS
AFAC	ASSUME AFAC DUTIES
LOIT	WAIT PRESCRIBED TIME
JON	TURN JAMMERS ON FOR SPECIFIED TIME
JOFF	TURN JAMMERS OFF

EVENT HAS OCCURRED

EVENT TYPE	ACTION
DAMG	MAKE AIR REPORT AND RETURN TO BASE IF LESS THAN 1/3 A/C LEFT CRASH PLANE IF NO A/C LEFT
EADF	CHANGE ALTITUDE IF MISSION SUCCESS TOO LOW, ATTACK AIR DEFENSE
FUEL	MAKE AIR REPORT AND CRASH PLANE

CRC, CRP, FACP

IF AIR ALERT AND IF HAVE DIVERT MISSION SEND NEW FLIGHT PATH

ELSE DO NOTHING

CC MSG   CC MSG

AFAC, GFAC

IF HAVE DIVERT MISSION, SEND NEW FLIGHT PATH

IF BUSY, PUT ON LOITER
ELSE LOOK FOR TARGETS

IF SEEN, SEND TO TARGET

ELSE, SEND TO ANOTHER FAC

CC MSG

As shown here, the simulation model of the pilot's decision processes looks similar in structure to the previous ASOC example. The specific steps a pilot might take are organized according to different stimuli. Shown at the left side of the pilot model are those actions taken in response to receipt of a control and coordination message. In the middle, we see various responses arranged according to what point in the air mission the pilot has reached. At the right are listed responses to certain unanticipated events. These events include being damaged by an enemy air defense unit, detecting that an air defense unit has acquired the pilot's aircraft, or running out of fuel.

Now, without belaboring this example, I would like to point out several features associated with such models. The first feature of this model is that it describes a specific set of responses. The decision model assumes as part of its construction that the pilot will confront only certain types of well-defined problems. For example, this model says nothing about how the pilot is supposed to react if an enemy interceptor engages his aircraft. In fact, the TAC ASSESSOR model does not simulate air-to-air engagements. Hence, the pilot model is not programmed to worry about such operations.

Thus, we see that models of this type are bounded by the specific problem structure assumed by the model developer. If a more flexible or robust decision model is required, the model developer must take the time and effort to define a wider problem structure.

A second feature of this type of model are the parameters and terms used to describe both the problem environment and the decision rules. Phrases in the example model such as "if busy", "send CC message", or "assume AFAC duties" mean specific concepts and operations in the model. Unlike in real life where such phrases may often represent vague or indefinite ideas, within the simulation model they must take on specific meaning. In real life, human beings compensate for this lack of precision by interpreting indefinite phrases in assumed context. In a cybernetic model of decisionmaking, the model developer must supply this assumed context through the way in which he associates specific actions with each phrase.

Thus, we have seen in this example two of the most common difficulties with building cybernetic decision models. I would now like to generalize on these, and other such difficulties.

Before turning to this slide, however, I state at the outset that I believe most of these modeling difficulties to be manageable ones. In developing the TAC ASSESSOR model, we realized that developing tactical decision models would be a difficult and complex task. To date, however, we have been generally pleased with the progress made on this model. Already,

we have begun using the TAC ASSESSOR model to assist in an analysis of tactical reconnaissance operations. We anticipate that in the next few months this model will greatly improve our ability to quantify the combat utility of various tactical reconnaissance systems.

TAC ASSESSOR was one of the first large-scale combat simulation models to employ explicit modeling of tactical decision processes. We are encouraged, however, to see similar techniques being employed in other combat simulations. We see this trend as indicative of the next generation of analytic tools for C3I research.

Now, our optimism notwithstanding, we know that real challenges still lie ahead in the modeling of tactical decision processes. And we recognize the need for help from others in meeting these challenges. Thus, it is in this spirit that I present my concluding remarks.

DIFFICULTIES ENCOUNTERED WITH TACTICAL DECISION MODELS

- DEFINING "PROBLEM STRUCTURE" FOR TACTICAL DECISIONS

  - VOCABULARY OF FORCE MANAGEMENT
  - HEURISTICS/PROCEDURES OF FORCE MANAGEMENT

- MODELING ADAPTIVE BEHAVIOR

  - SITUATION CONTEXT
  - DEFINING/SELECTING APPROPRIATE RULE SETS

- LACK OF EMPIRICAL DATA FOR MODEL VALIDATION

  - DOCUMENTED FORCE MANAGEMENT PRACTICES
  - REALISTIC, CONTROLLED EXPERIMENTS

SLIDE 12

As I illustrated with the last example, the model developer is faced with the problem of defining "problem structure" for the tactical decision processes. In real life, problem structure is dealt with almost subconsciously as the decisionmaker draws upon experience and knowledge to guide the form and content of a particular decision process. That is , we learn to recognize certain types of situations or problems and to call forth appropriate rules and procedures.

In developing a tactical decision model, we must explicitly define this structure through (1) the form in which we cast the problem, (2) the vocabulary we use to describe the problem, and (3) the heuristics or procedures we employ to solve the problem. While developing the TAC ASSESSOR model, we found (not too surprisingly) that opinions vary widely about such details. In many portions of the TAC ASSESSOR model, considerable debate arose over the "correct" way to describe a tactical problem or the "best" set of procedures to follow in solving a tactical problem.

Indeed, our attempts to build this model of tactical decision processes told us something about the real world -- that we all view combat operations and tactical force management differently. At this point, I don't know whether this is more a problem for the analyst or for the real-world tactical operator.

A second area of difficulty lies in the modeling of adaptive behavior. Decision processes in the real world tend to be adaptive in nature. Rarely are tactical decisionmakers confined to the rigid type of decision rules we saw in the TAC ASSESSOR examples. Unlike our present simulation models, humans have an ability to adapt decision rules to fit the problem or to completely abandon them for other sets of rules if conditions warrant. Humans also have an ability to modify goals and to make partial (or tentative) decisions when appropriate.

For simulation modeling, we are beginning to explore more powerful techniques for modeling adaptive behavior. These various techniques allow one to incorporate "learning" processes within the decision models and to adopt different scripts or sets of decision rules based on situation context. Yet, even with such techniques, a basic problem remains for the model developer to know what type of learning or adaptive behavior best represents the real world.

This brings me to the last point on this chart, the lack of empirical data for model validation. Again, I state that a major use of such models is to assist our understanding of operations in real tactical C3I systems. Thus, one goal of this descriptive model building is to emulate human decision processes with as much fidelity as possible.

Unfortunately, in the area of tactical force management, we have little (if any) documentation on how tactical decisions are made. In building the TAC ASSESSOR model, we relied principally upon the personal opinion of operational experts to guide our decision modeling. There existed no handy reference manuals to tell us precisely how various tactical problems are perceived or solved. As I mentioned before, the opinions of operational experts differed in many areas.

We also found that there are few opportunities to observe such decision processes in realistic settings. Our experience with CPXs and other training exercises suggested to us that too many artificialities and constraints were present to record valid observations.

So where does this leave the state of tactical decision modeling? In my last slide I would like to summarize a few thoughts and suggest a few potentially attractive ideas for the future.

FOR THE FUTURE

- CAREFUL APPLICATION OF SIMULATION MODELS

  - SENSITIVITY ANALYSIS vs ABSOLUTE RESULTS
  - COMPLEMENTARY RESEARCH

- CONTINUED IMPROVEMENT OF THEORETICAL APPROACHES

  - BASIC RESEARCH IN COGNITIVE SCIENCE
  - EXTRACT APPROPRIATE FINDINGS FOR C^3I ANALYSIS

- CONTINUED FOCUS ON APPLIED RESEARCH

  - DOCUMENT/CRITIQUE KNOWN DECISION PROCESSES
  - EXCHANGE FINDINGS WITHIN THE C^3I COMMUNITY
  - PROMOTE SYSTEMATIC, CONTROLLED FIELD RESEARCH
    OF C^3I DECISION PROCESSES

SLIDE 13

Considering the present level of sophistication of our tactical decision models, I believe we must be careful in the way we use them for C3I analyses. At present, such models are capable of emulating certain types of structured decision processes. Yet, they lack the scope and fidelity to truly simulate human decisionmaking in C3I. In addition, those decision models which exist reflect only one particular view of combat and tactical force managemnt. As we found with TAC ASSESSOR, many such views exist -- a problem which both analysts and operators will have to deal with.

Given this state of affairs, I believe is is appropriate to apply such models mainly to sensitivity analyses. That is, we should use such models to test the impact of different decision rules and decision styles on force management and combat effectiveness. We should use such models to provide us a better undertanding of where the sensitive interactions are in C3I systems. In addition, we must recognize that these limited models cannot provide a total answer to our questions concerning C3I requirements and utility. We must acknowledge the need to complement our simulation studies with research findings from other activities (eg, behavioral science research, field tests and exercises, and so forth).

Concurrently, the C3I community should continue to support the improvement of theoretical research in decisionmaking. The cognitive science field is rich with findings applicable to the tactical C3I problem. We have only begun to tap this field as a source of improved methodologies for C3I analysis.

And finally, to complement this theoretical work, we should continue to focus on applied research. After all, tactical force management is a very applied science and much remains for us to understand at the applied level.

But progress will not be achieved without effort. The various communities involved with C3I must work together to promote the three efforts I've listed here:

Known decision processes should be carefully documented -- not in the sense of prescribing how people should act, but rather as a means of communicating ideas about C3I processes and of allowing the community to critique and redefine these processes.

Secondly, there needs to be an increased exchange of research findings among the various organizations involved with C3I development, research, and training. For too long, these organizations have acted independently and, thus, have neglected the benefit of mutual dialogue.   (

Finally, there needs to be increased attention devoted to systematic, controlled field research of tactical decision

processes. We need to expand the flexibility and realism of CPXs, field tests, and field training programs to provide the community a valid means of collecting empirical data in this area.

Now, much of this is a fairly tall order for the C3I communities. Success in developing better tools and approaches to C3I analysis and training is not guaranteed. I have suggested a few ideas which could, perhaps, lead to further progress in this regard. But, it is a problem we are all faced with, and one which we must all deal with..

Thank you for your attention. I now invite your comments and questions.